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PHOTONIC CRYSTALS: CALCULATION OF THE TRANSMISSION SPECTRUM LIQUID CRYSTALS STRUCTURE

Pyatnov M. V.

Scientific supervisor – Associate professor Petrischeva G. P.

Siberian Federal University

Liquid crystals structures are of great interest today. This is due primarily to their use as a basic element of displays. But this does not exhaust all of their applications. Liquid crystals (LC) are usually attributed to one-dimensional photonic crystals (PC) (*Fig. 1*), this is due to the fact that they possess the basic properties inherent in photonic crystals, namely the ability to periodically change of dielectric properties in the sphere of spatial scale of optical wavelength order, and the most important feature of PC is the existence of photonic band gap (PBG). I.e. region of total reflection of light incident on the structure.

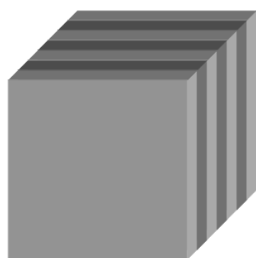


Fig. 1

General view 1D photonic crystal



Fig. 2

Nematic liquid crystal

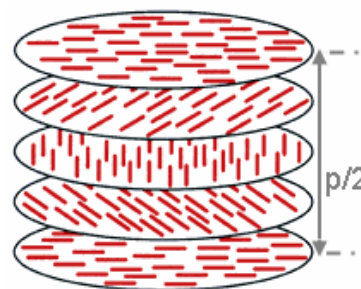


Fig. 3

Cholesteric liquid crystal

The peculiar structure of liquid crystals is that their molecules have an elongated shape, so that the optical properties of the molecules differ in different directions. If the molecules do not have any specific ordering it is Nematic liquid crystals (*Fig. 2*). Of particular interest are the structures of cholesteric liquid crystals (CLC). A CLCs have a helical structure (*Fig. 3*). It is also known as chiral nematic liquid crystals. They are organized in layers with no positional ordering within layers, but a director axis varies with layers. The variation of the director axis tends to be periodic in nature. The period of this variation (the distance over which a full rotation of 360° is completed) is known as the pitch, p . The pitch varies with temperature and it can also be affected by the boundary conditions when the CLC is sandwiched between two substrate planes. The crystal can transmit light only of the same name polarization, which coincides with the polarization direction of twist.

The purpose of the work was to simulate light propagation in cholesteric liquid crystals and to study the spectrum of light transmission. The classic way of solving this problem is the method of Jones. Jones matrix, which characterizes the environment (size of 2×2) takes into account waves spread in the environment of two polarizations. The main drawback of this method is that the method of Jones does not consider the reflection of light from the structure.

In the 70s Berreman proposed another method. The method is in finding the transmission spectrum using a matrix 4x4, characterizing the environment. Unlike the Jones method Berreman took into account not only the transmission, but also a reflection of the incident light. The method of Berreman propagation of light is described by Maxwell's equations taking into account the constitutive equations of the medium. As a result of mathematical operations, this method reduces to solving matrix form ordinary differential equation:

$$\frac{d}{dz} \begin{pmatrix} E_x \\ H_y \\ E_y \\ -H_x \end{pmatrix} = \frac{i\omega}{c} \begin{pmatrix} S_{41} & S_{44} & S_{42} & -S_{43} \\ S_{11} & S_{14} & S_{12} & -S_{13} \\ -S_{31} & -S_{34} & -S_{32} & S_{33} \\ S_{21} & S_{24} & S_{22} & -S_{23} \end{pmatrix} \begin{pmatrix} E_x \\ H_y \\ E_y \\ -H_x \end{pmatrix}$$

After making this equation it is possible to calculate the values of transmission coefficients for different frequencies of incident light.

The structure my investigation was considered to be consisting of a multilayer mirror and containing the CLC, located in the middle as a defect (*Fig. 4*). Both layers are PC and it has a characteristic period of dielectric constant variation. Therefore, as shown in *Fig. 5* and *6*, they both have a photonic band gap. In compiling them into a system, photonic band gaps overlap (*Fig. 7*). In the FC was defect modes gap formed. That is the light of certain frequencies that falls within the band gap of photonic crystals, is transmitted, coefficient 100%.

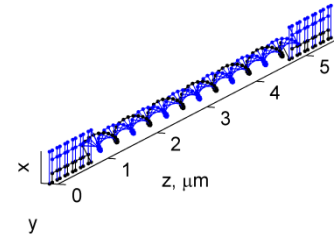


Fig. 4
Structure image

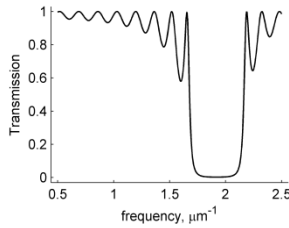


Fig. 5

Transmission spectrum of PC

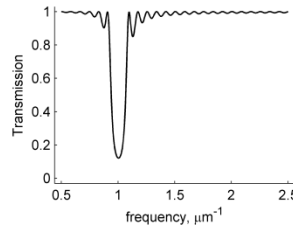


Fig. 6

Transmission spectrum of CLC

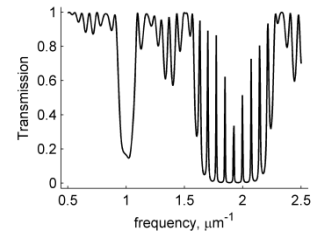


Fig. 7

Transmission spectrum of structure

The structure was investigated by varying the thickness of the defect. The number of defect modes depend on it, when the thickness of the band gaps are closer to each other.

The significance of this work is the development of the exact method for calculating the transmission spectrum of FC. The investigated structure has specific application in the optical or quantum electronics. Modern monitors are having a basic element of a similar structure called twist cell (*Fig. 8*) and each pixel contains it.

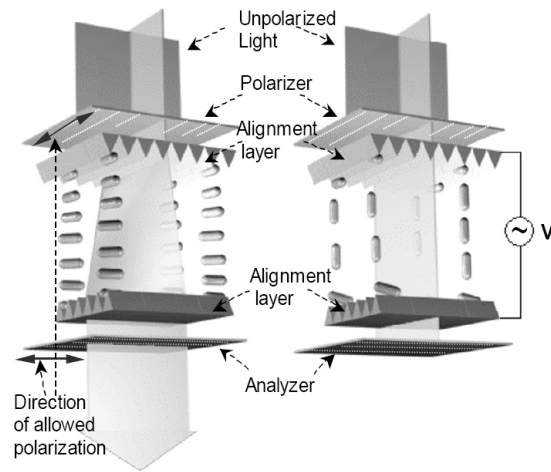


Fig. 8
Twist cell - basic element monitors

Polarized light enters the cell twist, passes it and changes its polarization. The desired wavelength can pass through the twist cell. Passage of light through such a structure depends on the frequency so the results of the research can be useful in developing new types of monitors.

Of course, this is not the only application of this work and research conducted on the basis of the method used here.